Report

Chair Report on the Common Thresher Shark (*Alopias vulpinus*) Stock Assessment Review

June 26-28, 2017

Southwest Fisheries Science Center
8901 La Jolla Shores Dr., La Jolla, CA 92037
La Jolla, CA 92037
858-546-7000

September 2017

Henrik Sparholt

Table of Contents

1. Executive summary

The Stock Assessment Review Panel met at NOAA's Southwest Fisheries Science Center in La Jolla, California, from 26-28 July 2017 to review a stock assessment of Common Thresher Shark (*Alopias vulpinus*).

The Fisheries Resources Division (FRD) of Southwest Fisheries Science Center (SWFSC) requested an independent peer review of the benchmark stock assessment developed for the common thresher shark stock along the west coast of North America.

The common thresher shark fisheries of the USA and Mexico are independently managed by the Pacific Fishery Management council (PFMC) and the Instituto Nacional de Pesca (INAPESCA), respectively.

Common thresher shark fisheries in both the USA and Mexico have declined substantially since the start of commercial fisheries for this stock in the late 1970s, with total removals estimated to be <200 t in 2014. The current USA fishery management plan for this stock of common thresher sharks includes a harvest guideline of 340 t based on an unpublished analysis of USA data and is derived from the optimum yield for vulnerable species, which is defined as 0.75*MSY (or reasonable proxy).

This is the first stock assessment of common thresher sharks along the west coast of North America that incorporates information from all fisheries exploiting the population. The Stock Synthesis (SS) modeling platform was used to conduct the analysis. The model began in 1969, assuming the population was at equilibrium prior to 1969 in a near unfished state, and ended in 2014, which was the last year that data was available.

A key uncertainty in the stock assessment is the reproductive biology of this stock. Previous research suggested that female sharks had an age of maturity of 5 years of age and an annual reproductive cycle. The review scrutinized the evidence for this and found that potential mis-specification of pelagic thresher shark as common thresher shark and problems in determining the maturity stage pointed at an older age of maturity and maybe a biennial reproductive cycle. A recent study on the reproductive biology of the western North Atlantic stock of common thresher sharks demonstrated a much older median age of maturity (age-12) and longer reproductive cycle (biennial or triennial cycle). Another previous study from the Indian Ocean which showed that common thresher shark has an age of maturity of 5 years of age and an annual reproductive cycle was during the review, discovered to be a likely mis-specification of pelagic thresher shark to common thresher shark. A recent FAO paper working paper was provided by the reviewers, which described this likely mis-specification in details. The review found the evidence strongest for the late maturity and biennial reproduction. This was therefore selected for the base run of the assessment model. Sensitivity model runs indicated that changing the maturity and fecundity schedules resulted in substantial differences in the trend and scale of the

estimated population dynamics. However, in all scenarios the stock was determined to be not overfished and that overfishing is not taken place, and that the current management harvest guideline of 340 t is living up to the US guidelines for fisheries management for this vulnerable species of an optimum yield of 0.75*MSY.

The other aspects of the assessment were judged to be based on the best available science and done in an un-biased, comprehensive way and with the use of an appropriate assessment tool. The data were judged to be compiled in an appropriate way. The assessment model configuration, catch assumptions, and input parameters (e.g., natural mortality, spawner-recruit relationship) were reasonable. The models were appropriately configured, assumptions were reasonably satisfied, and primary sources of uncertainty was well accounted for, partly within the models and partly by running sensitivity analysis of plausible alternative scenarios, mainly with varying natural mortalities and Z_{frac} (a spawner-recruit relationship parameter) values.

The Panel agreed that the assessments was effective in delineating stock status, determining *BRP*s and proxies. While an MSY-related stock size is calculated, the results indicate that small increases in fishing mortality above that at MSY could result in rapid declines in stock size. In other words, stock size at MSY is on the declining slope on the left side of the S-R curve. This suggests caution in implementing an MSY target as an objective.

The review process was effective in structuring a critical review of the work of the SWFSC and in identifying areas of concern and needs for additional work in future assessments.

2. Background

2.1 Introduction

The Stock Assessment Review Panel met at NOAA's Southwest Fisheries Science Center in La Jolla, California from 26-28 of July 2017 to review a stock assessment for Common Thresher Shark (*Alopias vulpinus*).

The Review Committee was composed of Joseph Powers (USA), Rui Coelho (Portugal) and Dr. Henrik Sparholt (Denmark).

The Review Committee was assisted by Steve Teo (SWFSC) who did the assessment, the presentations, and the extra model runs the Panel wanted during the meeting. Suzanne Kohin (SWFSC) presented the reproduction biology of thresher shark. Furthermore, the Panel was assisted by Kevin Hill, P.R Crone, Hui-Hua Lee, Helena Aryafar, Antonella Preti, and Heidi Dewar, all from the SWFSC.

The meeting was open to the public, but nobody from the public attended.

The Fisheries Resources Division (FRD) of Southwest Fisheries Science Center (SWFSC) requested an independent review of the benchmark stock assessment developed for the common thresher shark stock along the west coast of North America. The biological range of the stock spans the west coasts of Mexico, the United States of America (USA), and Canada. The common thresher shark fisheries of the USA and Mexico are independently managed by the Pacific Fishery Management council (PFMC) and the Instituto Nacional de Pesca (INAPESCA), respectively. However, there are no current nor historical fisheries along the west coast of Canada and in international waters that target common thresher sharks and bycatch appears to be rare. Common thresher shark fisheries in both the USA and Mexico have declined substantially since the start of commercial fisheries for this stock in the late 1970s, with total removals estimated to be <200 t in 2014. The current USA fishery management plan for this stock of common thresher sharks includes a harvest guideline of 340 t based on an unpublished analysis of USA data and is derived from the optimum yield for vulnerable species, which is defined as 0.75*MSY (or reasonable proxy).

This is the first stock assessment of common thresher sharks along the west coast of North America that incorporates information from all fisheries exploiting the population. The Stock Synthesis (SS) modeling platform was used to conduct the analysis. The model began in 1969, assuming the population was at equilibrium prior to 1969 in a near unfished state, and ended in 2014, which was the last year that data was available. The stock assessment considered this population to be a single, well-mixed, trans-boundary stock and relied heavily on data from both the USA and Mexico. However, it is important to note that the analysts who reconstructed the catch time series for Mexico's fisheries were not available for the peer review. A key uncertainty highlighted in the stock assessment is the reproductive biology of this stock of common thresher sharks. Previous research on this stock of common thresher shark suggested that female sharks had an age of maturity of 5 years of age and an annual reproductive cycle. However, a recent study on the reproductive biology of the western North Atlantic stock of common thresher sharks demonstrated a much older median age of maturity (age-12) and longer reproductive cycle (biennial or triennial cycle). Sensitivity model runs indicated that changing the maturity and fecundity schedules resulted in substantial differences in the trend and scale of the estimated population dynamics. The stock assessment provides the basis for scientific advice on the status of common thresher sharks along the west coast of North America. An independent peer review of the assessment is therefore essential. The Terms of Reference (ToRs) of the peer review are given below.

Supporting documentation for the common thresher shark assessment was prepared by the SWFSC.

2.2 Review of Activities and Process

Before the meeting, assessment documents and supporting materials on biology were made available to the Panel by email.

The meeting opened on the morning of Monday, 26 June, with welcoming remarks and comments on the agenda by Deputy Director Dr. Dale Sweetnam (SWFSC). All participants were introduced at the opening of the meeting. Following introductions, sessions on the 26 June were devoted to presentations and discussion of the assessment and reproductive biology of the stock.

The Panel requested additional analyses to re-evaluate the assessment based on selected input parameters for M (natural mortality) and Z_{frac} (parameter in the stock recruitment model). These were presented on Tuesday 27 June.

Between Monday and Tuesday, one of the reviewer contacted a colleague, expert in Indian Ocean sharks and he had just published an FAO paper about the likely mis-specification of common thresher shark in the Indian Ocean. This was relevant for the Panels' decision on the reproductive biology of the species, because it strongly indicated that all these common thresher shark from the Indian Ocean (which were the only substantial data on early maturity of common thresher shark) were instead pelagic thresher shark. Thus, this further weakened the support for the Smith (2008) conclusion of early maturation of specimens of the current Pacific stock. The Panel asked whether Smith was still around and could be contacted and asked about the issue. The SWFSC had actually already talked to her and she was very helpful and explained that she found the aspects presented in the paper by Aryafar *et al.* (2017) about the reproductive biology of the stock and tabled at the present meeting, quite sensible and she did not have strong views regarding sticking to her 2008 conclusion. The Panel found this reassuring, because often the material presented in a paper (here Smith 2008) are not the full picture of the case, but here it seemed to be.

Further analysis was requested using the late maturation and low fecundity scenario to look at model diagnostics for a new base case (Scenario A with M=0.08 and Z_{frac} =0.8). These were done and presented the same day, Tuesday 27 June.

An internal model/data inconsistency was discovered. The model ran with the juvenile S4 and S5 indices (abundance of primarily age-0 common thresher sharks based on logbooks from the USA nearshore set gillnet and small-mesh drift gillnet fishery during 1985 – 1993 resp 1994 – 2014), gave a quite different assessment of the stock's trend, in terms of not showing an improvement in stock size in recent years and only little reduction in F in recent years.

A new run was made with the very low M=0.04, and this made the problem described above to vanish. The Panel was quite uncertain what to believe most in, the higher M from meta-analysis or the low M from model/data indications. After reflection, the model run with this low M (of 0.04) was selected as the best model, and was selected as the base

case. Sensitivity analysis was done for a set of plausible M and Z_{frac} values and fecundity at 4 pups per year, in order to illustrate for managers the level of uncertainties in the assessment. More precise knowledge on the reproductive biology and of M of this stock is needed in order to improve this assessment in the future.

The Panel spent the final day, Wednesday 28 June, looking at the diagnostics of the new base case assessment, to check that it did not contain any new "surprises". All diagnostics seemed ok and the Panel therefore decided to stick to that assessment as the best available one for this common thresher shark stock.

The Panel and SWFSC worked collectively during the meeting and reached agreement and consensus on the assessments. The meeting was collegial and conducted in a good and constructive atmosphere.

The completion of the Assessment Summary Report, was accomplished by correspondence on 14 July 2017, evaluating each ToR that had been put forward to the Panel. The Chair compiled and edited the draft Summary Report, which was distributed to the Panel for final review before being submitted to the SWFSC and CIE. Additionally, each of the CIE Panelists drafted and submitted an independent reviewer's report to the SWFSC and CIE.

The Panel agreed that the assessment was effective in delineating stock status, determining *BRP*s and proxies. Issues and concerns are discussed below. The review process was effective in structuring a critical review of the work of the SWFSC and in identifying areas of concern and needs for additional work in future assessments.

3. Review of common thresher shark

Common thresher sharks (*Alopias vulpinus*) along the west coast of North America are seasonally distributed in coastal waters from British Columbia, Canada to central Baja California, Mexico. Juvenile common thresher sharks tend to remain in shallow, nearshore areas over the continental shelf, especially within the Southern California Bight (SCB), which is an important nursery area. The distributions of common and bigeye thresher sharks are thought to overlap partially, with bigeye thresher sharks generally exploiting deeper waters. In contrast, there is relatively little overlap in the distributions of common and pelagic thresher sharks.

Common thresher sharks along the west coast of North America are assumed to be a single, well-mixed stock. This assumption is supported by their genetics, tagging data, and seasonal movements. The mitochondrial genetic sequences of common thresher sharks from California waters are not significantly different from Oregon-Washington waters, but both are significantly different from other sampling locations, noting that there have not been any published comparisons with samples from Mexico. There is also no evidence of pupping and nursery grounds outside of the SCB. Tags from common

thresher sharks tagged in the SCB have been returned from California, USA, and Baja California, Mexico. There is also unlikely to be substantial interchange of individuals between this stock and other common thresher shark stocks, because the geographically closest stock is likely to be along the west coast of Chile.

The history of fisheries for this stock of common thresher sharks in USA waters is not well known prior to the 1970s, but small amounts of catch were recorded by a variety of USA commercial and recreational fisheries. The most important USA commercial fishery for common thresher sharks is the swordfish/shark drift gillnet (USDGN) fishery, which started in 1977 - 1978. Although the primary targets were initially common thresher and shortfin mako sharks, fishermen soon switched to primarily targeting swordfish because of substantially higher ex-vessel prices. Fishing operations of the USDGN fishery have been heavily regulated to reduce adverse interactions with other fisheries, fishing mortality of common thresher sharks, and incidental bycatch of marine mammals and sea turtles. Secondarily, nearshore set gillnets and small-mesh drift gillnets (USSN) occasionally catch young-of-year and juvenile common thresher sharks as bycatch. There is also a small USA recreational fishery in Southern California (USREC) that targets adult common thresher sharks but catches are usually relatively low.
The historically most important fishery for common thresher sharks in Mexico waters was the Mexico drift gillnet (MXDGN) fishery, which started in 1986. The fishing gear and operations of this fishery were similar to the USDGN fishery, with swordfish and pelagic sharks as the primary targets. The number of MXDGN vessels began to decline in the mid-1990s as vessels began converting to longline gear. The MXDGN fishery has been prohibited since 2010 by six Mexican federal regulations. The Mexico artisanal (MXART) fishery operates from small boats called pangas, using various nearshore gears that are set and hauled by hand, along the entire Pacific coast of Mexico. The size and history of this fishery is poorly known, but it has likely existed since the early 20th century. Only a small portion of pangas are allowed to fish for sharks. For example, there were 50 shark permits for this fishery in Baja California in 1998, representing about 180 out of more than 2000 pangas in total.

There are no historical nor current fisheries along the west coast of Canada that target common thresher sharks and bycatch appears to be rare. There are also no known historical nor current fisheries that target this stock of common thresher sharks in international waters and bycatch is expected to be minimal, given the largely coastal distribution of this population.

3.1 Evaluation of Terms of Reference 1-3

The evaluation of the first three Terms of Reference:

1. *Evaluate the assessment model configuration, assumptions, and input parameters (e.g., natural mortality, spawner-recruit relationship, reproductive biology) to determine if the data are properly used, input parameters are reasonable, models*

are appropriately configured, assumptions are reasonably satisfied, and primary sources of uncertainty are accounted for.

2. *Evaluate the ability of the model, combined with available data, to assess the current status and productivity of common thresher sharks along the west coast of North America.*
3. *Evaluate the adequacy of sensitivity analyses to represent the main axes of uncertainty in the assessment.*

3.1.1 Catch data

Generally, the construction of the time series of catches were done in a reasonable way. Clearly there are a lot of uncertainties especially back in time. One of some concern to the Panel was the artisanal Mexican fishery (*pangas*). There were around 2000 small boats, with only a minority having license to fish for sharks. The Panel raised the possible concern that a large number of those vessels (that do not have shark licenses) could also be by-catching sharks that had to be discarded due to not having shark licenses, likely with high discard/post-release mortality rates. This could represent an important source of fishing mortality not currently accounted in the catches of this fishery. This issue was discussed, but unfortunately the Mexican analysts who reconstructed the catch time series from Mexico were not present at the meeting. However, the modelers explained that the Mexican data is also coming from market sampling and not only port-sampling, and there is likely very little discarding on this fleet. The review meeting would have benefitted from a participation of a Mexican scientist with expert knowledge of the Mexican fishery.

3.1.2 CPUE standardization

It was nice to see that a proper GLM type analysis was done with the CPUE data in order to obtain a time series index that reflects the stock size dynamics over time. Often, in fish stock assessments, this is not done properly or only superficially. The CPUE standardization method used was similar for the various CPUE series, specifically GLM models using the Delta lognormal approach. The Panel recognized that this method is commonly used in CPUE data standardization. It is especially used when part of the data is composed by zeros, as is the case of the CPUE datasets analyzed.
The Panel noted that the catches were recorded and modeled in numbers (N, discrete distribution) that was then transformed into a continuous variable in the log scale (log (N)). Another possible approach suggested by the Panel would be to model the catch directly in numbers using a discrete distribution, as for example the Negative Binomial, possibly with zero inflation if needed. Another suggested alternative was a Tweedie distribution (generalization of the exponential family) that can model the mass of zeros and the continuous component for the positives in the same model. This is something that can be further explored in the future.

The Panel noted that the index from the main fishery (USDGN) had to be broken into 3 separate time series due to changes in regulations, and included a period in the middle without information (i.e., 1985-1991). The Panel recognized and accepted that this had to be done because of the difficulty of modeling changes in regulations in the GLM models, if a unique and continuous time series were to be used. However, by having to break the time series from the main fishery in 3 sections, the overall contribution to the model of each section was also lower (except for S2 in the middle period that still contributed significantly). The Panel suggested that in the future, a new attempt could be tried for the entire time series combined, trying to account for the changes in management regulations (mainly seasonal and spatial closures) as detailed spatial and seasonal effects in the GLM to try to compensate for those changes in the fishing operations through time.
Finally, the Panel commented and discussed the targeting variable that was used, based on ranking the swordfish catches within each year (used as a proxy of swordfish *versus* sharks targeting). One possible issue that was raised related with such method is that if within specific years there are consistently the same targeting for the same species, there will still be categorization and ranking within each year that is not necessarily consistent with the overall inter-annual variations in the targeting effects of the fleet. One possible suggestion by the Panel to address this issue in the future would be to test and consider interactions between year and targeting effects. The use of vessel effects, possibly as a random variable, was also suggested, as that could also bring to the CPUE standardization variability associated with the different practices of the various vessels operating in the fleet.

3.1.3 Reproductive biology

Biology, especially the reproductive biology, was a major source of uncertainty in the stock assessment. The base case model in the original stock assessment considered a hypothesis with a more productive biology, based on a smaller size at maturity and annual reproductive cycle. However, since then, there have been concerns about the original biological studies in the Pacific, with new hypothesis that size at maturity could be larger (more similar to the one described for the Atlantic) and periodicity could be biennial.

The main issues identified with the original biological studies are likely related with eventual species misidentification in threshers (between common and pelagic thresher), an issue that is now also suspected in some of the original studies in the tropical Indian Ocean. As pelagic thresher is a much smaller species, the size at maturity is also smaller, and if there is misidentification, this will have a great impact in the estimation of the size at maturity. There may have also been some issues with the original measurements from the observers.

The Panel agreed with the new hypothesis of the biology (larger size at maturity and possibly a biennial reproductive cycle). However, using this new biology created some additional convergence problems in some of the models that in general needed lower

values of natural mortality (M) to converge. This issue was explored at great length during the meeting, with the modeler exploring multiple scenarios (especially combinations of M and Zf_{rac}) to investigate which combinations had problems of convergence, likely caused by conflicts in the data (CPUE, size and biology). The Panel agreed that the uncertainties in the reproductive biology of the common thresher shark in the Pacific are a source of major uncertainty in the stock assessment model and should be further studied.

3.1.4 Stock-Recruitment

The stock recruitment model chosen for use in the common thresher assessment was that of Taylor et al. (2013). This model is especially useful for species with very low fecundity like sharks. This model is essentially a modification of a Ricker function with an additional term, β, which defines the strength of the depensation effect at larger stock sizes. Importantly, the particular parameterization allows for the use of basic reproductive information more directly in the specification of the slope of the stock-recruitment curve at the origin. The parameterization used was:

$$R_y = B_y exp\left[-z_0 + (z_0 - z_{min})\left(1 - \left(\frac{B_y}{B_0}\right)^{\beta}\right)\right]$$

where recruitment R in year y is in number of pups, B_y is the number of pups born at the beginning of the recruitment process in year y (B_0 denotes equilibrium pup production when there is no fishing and $S_0=R_0/B_0$ is the equilibrium survival when there is no fishing). Additionally,

$$z_{min} = z_0(1 - z_{frac}) = z_0 - z_0 z_{frac}\ ; \quad z_0 = -ln(S_0)\ ;\ z_0 - z_{min} = z_0 z_{frac}$$

and z_{frac} is a fraction ranging from 0 to 1. Hence, knowing S_0, B_0, z_{frac} and β completely defines the function.

The Panel noted that the fraction z_{frac} functions similarly to the steepness parameter of more commonly used Beverton-Holt stock-recruitment models. It defines the slope of the S-R curve at the origin, i.e. the maximum recruitment rate that can be produced when stock sizes approach zero. And similar to steepness specifications, there was little information in the data to determine z_{frac} and, thus, alternatives were explored in the assessment through sensitivity analyses.

The Panel noted that there was not a strong biological explanation for how depensation was occurring in common thresher to support the choice of a Ricker-like form, other than it was originally applied to a shark species. Additionally, it was noted that similar to most fish stocks, the assessment model assumed that all density-dependence in common thresher over their lifespan occurred in the few months after their birth. In some fish stocks, this is a reasonable assumption. But, perhaps there are other stages in a shark's life where density-dependence can occur (nursery areas?). This supports the need for more basic research on reproductive biology and life history.

Other forms of the stock-recruitment function could have been explored which would have the same effect of rapid declines when the stock size was low. One example might be a basic hockey stick model where the recruitment is constant over stock size until it reaches a threshold at which it declines linearly to the origin. Care would then have to be taken in determining the slope because there is a maximum border of this due to the low fecundity of the species. However, this model and others would likely have produced similar results. Any function with steep declines at low stock sizes would be compatible with shark life history. The Panel believes that the resulting dynamics of common thresher stock-size over the years and basic status of the stock is relatively robust to the functional form chosen.

An implication of the stock-recruitment results and of shark life histories, in general, is that there is little surplus in recruitment to be taken as yield as the fish get older. While an MSY-related stock size is calculated, the results indicate that small increases in fishing mortality above that at MSY could result in rapid declines in stock size. In other words, stock size at MSY is on the declining slope on the left side of the S-R curve. This suggests caution in implementing an MSY target as an objective.

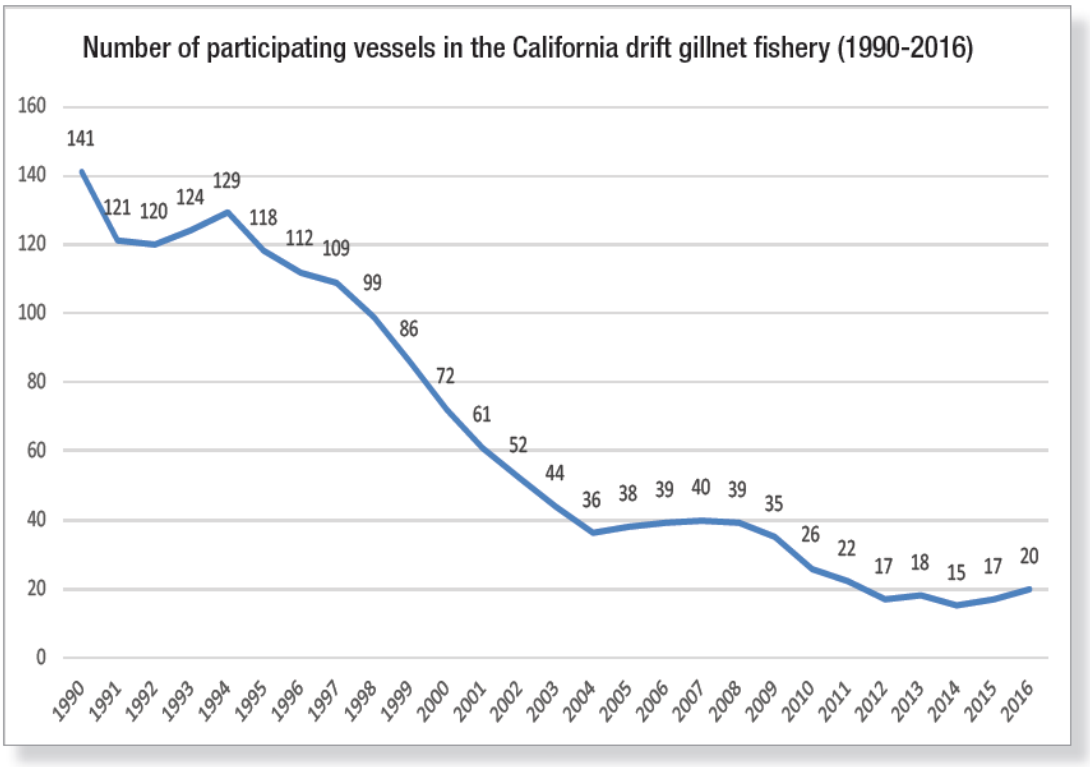
3.1.5 Natural mortality M

When the reproductive biology was decided upon M needed to be adjusted. This was because a low pup production per year by each female, means that the stock will collapse even in the case of no fishery, if M is assumed higher than 0.14. This was judged unrealistic.

A model run where M was allowed to be estimated by the model gave very low values of M of about 0.03. Very low Ms corresponds to very high maximum age. M values of 0.04, 0.06 and 0.08 mean that 1% of the stock in case of no fishing will be about 115, 77 and 58 years old, respectively. Based on the meta-analysis of M's relation to age at first maturity and to max age, the lower 95% confidence interval was 0.06. Runs with M equal to 0.6 and 0.8 (and Z_{freac} between 0.6-0.9) did not deviate much from each other in terms of model performance. The Panel found that a max age of 58 years was more realistic than 77 years and therefore tentatively decided on that value for a new base run.

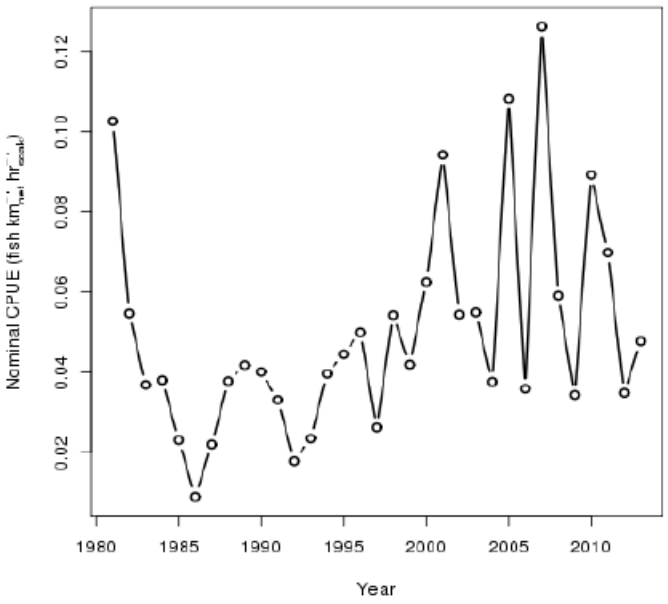
However, runs with M=0.08 and Z_{frac}=0.8 gave problems with internal consistencies of the model and data. Leaving out the S4 and S5 indices (abundance of primarily age-0 common thresher sharks based on logbooks from the USA nearshore set gillnet and small-mesh drift gillnet fishery during 1985 – 1993 resp 1994 – 2014), of the modelling gave a very different stock trend over the recent years, with very low stocks sizes compared to keeping these indices in the model. M had to be reduced to 0.04 and Z_{frac} to 0.5 before these inconsistencies vanished. After long discussions, it was agreed to use this run as the best description of the stock development and status, as the base run. This

decision was reached knowing that it meant that M was quite outside the range indicated by the meta analysis of max age and age of maturity, that there would be a very substantial number of very old fish in the plus group (25+), which nobody seems to know where they are in the ocean, and that max age would be extremely high, 115 years. This was regarded as the best compromise between the conflicting signals in the data and knowledge about the reproductive biology. It gave a strong downward trend in fishing mortality which is consistent with the strong decline in fishing effort as documented in Anon. 2017, and shown in the figure below. Other scenarios were explored and selected to show in a balanced way, realistic alternative estimates of the stock development and status. Fortunately, they all gave the same overall picture of a stock not being overfished and overfishing not taking place at present.



Source: NOAA Fisheries West Coast Region Observer program records

3.1.6 Additional evaluation of the base model



Even though the commercial drift gill net fishery cpue time series was broken into three sets (S1 1982-1984, S2 1992-2000, and S3 2001-2013) due to shifts in targeting and regulations, one might use the entire time series (see figure above) as a validation of the model stock trends. The problem with breaking it up into three sets is that the information contained in the difference in levels between the three sets are not used in the assessment model. However, it can be expected that the level in S1 is too high due to targeting thresher shark in that period, and that the level in S3 is too low due to mainly protected area regulations. This leads to the conclusion that the stock must be higher in recent years than in the start of the time series and significant higher than in the middle period. Thus, this development of the stock over the period 1980-2013 should be reflected in any model that attempts to assess the historical development of the stock. The base model run did fulfill this criteria.

3.1.7 Stock Status

The assessment is relatively robust in showing that stock sizes declined in the early years while experiencing high catches. When catches were reduced, the stock recovered. The estimated degree and timing of recovery are heavily dependent on uncertainties in

reproductive biology and life history characteristics. The assessment choices made by the assessment team and the Panel opted for statistical fits to the data, recognizing the apparent uncertainty in natural mortality rate, gestation, reproductive cycle. Nevertheless, the Panel is confident that current stock size is well-above MSY-related limits established in the US management system.

The base-case model indicates:

Number Adult Females in 2014	136,800
Number Adult Females at MSY	101,500
Number Adult Females at MSST	97,440
Fishing Intensity (1-SPR average 2012-14)	0.10
Fishing Intensity (1-SPR at MSY)	0.45
Catch in 2014	~160t
MSY	718t

MSST is Minimum Stock Size Threshold = (1-M) x stock size at MSY, where natural mortality rate M is specified as 0.04.

Therefore, common thresher is not overfished in that the adult female stock size is greater than that at both MSY and MSST and the stock is not undergoing overfishing because current fishing intensity is less than that which would produce MSY.

However, the Panel cautions that the uncertainties in life history, reproductive biology and the ensuing implications for the stock-recruitment relationship are large. Therefore, projections of stock size using the current assessment and stock-recruitment model will be extrapolating beyond the data and will also be very uncertain. While the Panel is confident that the stock is not currently overfished or undergoing overfishing, we are less certain about catch strategies that would be required to achieve MSY. If management were to pursue a policy of something close to MSY, then the ability to precisely determine the strategy to achieve this is severely limited by uncertainties in basic biological information as noted above. However, under current catch policies, the status is robust.

It is also noted that MSST and MSY stock size may not be particularly precautionary for this shark species. Generally, MSST is specified to allow some flexibility if stock size declines below that at MSY before a more rigorous management response is initiated. However, the stock sizes at both MSST and MSY for common thresher are both on the declining slope of the stock-recruitment curve at lower stock size. This further suggests that additional biological information is needed if an MSY policy is to be precisely pursued.

3.2 Evaluation of Terms of Reference 4

The evaluation of the fourth Term of Reference:

4. *Recommendations for future research priorities and further improvements to the assessment model.*

The Panel suggests the following:

- The survey design and protocols of the USA juvenile thresher shark survey could be reexamined and improved. Especially a random sampling design and access to MPAs could be considered.

- Catch and catch-at-size estimates from USA fisheries, especially the USA recreational fishery, should be improved. Information on recreational fishing from private vessels is obtained using surveys, which are available in a comprehensive coastwide marine recreational fishery database (RecFIN; http://www.recfin.org). The panel was informed that the information on common thresher sharks caught by anglers on private vessels is highly limited.

- It would be important for the quality of the assessment if the catch and catch-at-size estimates from Mexico fisheries could be improved following more traditional monitoring approaches.

- The use of the low fecundity stock recruitment relationship requires further research.

- It might be an idea to try a hockey stick S-R model following the ICES guidelines, allowing knowledge from other stocks, preferably shark stocks, to inform the modelling.

- There are clearly strong density dependent factors operating on the stock, preventing it from being much bigger than it was at the start of the time series and at the end of the time series where fishing also is very low. All of this density dependence is at present in the modelling assigned to the short life history period (a few months) from pub extrusion to recruitment to the fishery. This seems unrealistic. As a long term research issue it seems relevant to look into density dependent factors in growth, natural mortality, maturity (age at maturity, fecundity). One possibility could be to "learn" from other shark stocks, by way of meta-analysis.

- Reproductive biology: The current lack of knowledge and uncertainties associated with the reproductive biology of common thresher shark in the Pacific is likely the main cause of uncertainty in the stock assessment model. While most cases

and sensitivities tested with various hypotheses do not affect the stock status, in some cases there are problems of data conflicts in the model that needs further exploration. As such, it is highly recommended to continue the biological studies to further investigate the reproductive biology of this population, especially in terms of the size at maturity, age at maturity, and reproductive cycle/periodicity.

- Size samples: size samples seemed adequate from some fisheries (e.g., USDGN) but very limited in others, especially for the US recreational (USREC) and the Mexico fisheries (MXDGN and MXLL). Especially in those cases with very limited information, there was the need to assume similar size structure (i.e. similar selectivity) to some of the other fisheries with more information. This might be an important source of uncertainty in the current model and as such we recommend more effort to be put in collecting size data from those fisheries, preferably with sex-information.

- CPUE standardization: While the overall CPUE standardization process seemed to follow the current practices in fisheries, especially with large pelagics, there were some issues that could be the focus for future work and research. Specifically, we recommend testing some alternative distributions (e.g., Negative Binomial or Tweedie), consider/test the inclusion of interactions, test the possibility of modeling the USDGN as a single time series (using detailed spatial and seasonal effects to try to account for spatial/seasonal changes in management), and consider using vessel effects as a random variable to add variability associated with different vessels of the fleet.

- Low fecundity stock recruitment relationship: The use of the relatively new low fecundity stock recruitment (Taylor *et al.* 2013) seems to be appropriate for sharks in general, particularly for Lamniformes as the common thresher that has some of the lowest fecundities within sharks. However, this low fecundity stock recruitment relationship is relatively new and has not yet been fully tested. Therefore, while we agree with its use for this assessment, we also recommend that further work and research is conducted to fully test this stock recruitment relationship.

3.3 Evaluation of Terms of Reference 5

The evaluation of the fifth Term of Reference:

5. *Brief description on Panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations.*

The process went very well. Description of the discussions of the main issues are given above. The SWFSC, especially Steve Teo, was very supportive and skillful in providing the Panel with several extra assessment model runs and plots of selected diagnostics in a speedy and effective way during the meeting and in the evenings between the meeting days.

Much of the discussion was around the basic reproductive biology of the common thresher shark stock. The data and knowledge available were scrutinized, and compared to data from other common thresher shark stocks especially from the West Atlantic.

The Panel was little bit uncertain about the required format of the Summary Report. This format was not described specifically in the "Statement of Work" document sent to the Panel. The format was therefore agreed with the SWFSC representatives at the meeting and it is the one followed in the present report. It would good if the Statement of Work" is more specific on the format of the Summary report.

4. Appendixes

4.1 Bibliography of materials provided for review

Teo, Steven L. H.; Rodriguez, Emiliano Garcia; and Sosa-Nishizaki, Oscar. 2016. Status of common thresher sharks, *Alopias vulpinus*, along the west coast of North America. NOAA-TM-NMFS-SWFSC-557.

Teo, Steven L. H. 2017. Population dynamics of common thresher sharks along the West Coast of North America, assuming alternative reproductive biology and natural mortality parameters. Fisheries Resources Division, Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 8901 La Jolla Shores Drive, La Jolla, CA 92037, USA.

Aryafar, Helena; Preti, Antonella; Dewar, Heidi; and Kohin, Suzanne. 2017. Re-examination of the reproductive biology of common thresher sharks along the west coast of North America. Fisheries Resources Division, Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 8901 La Jolla Shores Drive, La Jolla, CA 92037, USA.

Romanov, Evgeny. 2015. Do common thresher sharks *Alopias vulpinus* occur in the tropical Indian Ocean? IOTC Working Party on Ecosystems and Bycatch (WPEB) Olhão, Portugal.

Anon. 2017. FAQs: West Coast drift gillnet (DGN) fishery & protected species. U.S. Department of Commerce, National Oceanic & Atmospheric Administration, National Marine Fisheries Service, West Coast Region.

4.2. A copy of the Statement of Work

Statement of Work
National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review

Status of Common Thresher Sharks, *Alopias vulpinus*, along the West Coast of North America

Background
The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards.
(http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf).
Further information on the CIE program may be obtained from www.ciereviews.org.

Scope
The Fisheries Resources Division (FRD) of Southwest Fisheries Science Center (SWFSC) requests an independent review of the benchmark stock assessment developed for the common thresher shark stock along the west coast of North America. The biological range of the stock spans the west coasts of Mexico, the United States of America (USA), and Canada. The common thresher shark fisheries of the USA and Mexico are independently managed by the Pacific Fishery Management council (PFMC) and the Instituto Nacional de Pesca (INAPESCA), respectively. However, there are no current nor historical fisheries along the west coast of Canada and in international waters that target common thresher sharks and bycatch appears to be rare. Common thresher shark fisheries in both the USA and Mexico have declined substantially since the start of commercial fisheries for this stock in the late 1970s, with total

removals estimated to be <200 t in 2014. The current USA fishery management plan for this stock of common thresher sharks includes a harvest guideline of 340 t based on an unpublished analysis of USA data and is derived from the optimum yield for vulnerable species, which is defined as 0.75*MSY (or reasonable proxy).

This is the first stock assessment of common thresher sharks along the west coast of North America that incorporates information from all fisheries exploiting the population. The Stock Synthesis (SS) modeling platform was used to conduct the analysis. The model began in 1969, assuming the population was at equilibrium prior to 1969 in a near unfished state, and ended in 2014, which was the last year that data was available. The stock assessment considered this population to be a single, well-mixed, trans-boundary stock and relied heavily on data from both the USA and Mexico. However, it is important to note that the analysts who reconstructed the catch time series for Mexico's fisheries will not be available for the peer review. A key uncertainty highlighted in the stock assessment is the reproductive biology of this stock of common thresher sharks. Previous research on this stock of common thresher shark suggested that female sharks had an age of maturity of 5 years of age and an annual reproductive cycle. However, a recent study on the reproductive biology of the western North Atlantic stock of common thresher sharks demonstrated a much older median age of maturity (age-12) and longer reproductive cycle (biennial or triennial cycle). Sensitivity model runs indicated that changing the maturity and fecundity schedules resulted in substantial differences in the trend and scale of the estimated population dynamics. The stock assessment provides the basis for scientific advice on the status of common thresher sharks along the west coast of North America. An independent peer review of the assessment is therefore essential. The Terms of Reference (ToRs) of the peer review and the tentative agenda of the meeting are below.

Requirements

NMFS requires a review chair who has a working knowledge and recent experience in the application of fisheries stock assessment processes and two (2) reviewers to conduct an impartial and independent peer review in accordance with the SoW, OMB guidelines, and the ToRs below. The Chair would ensure that reviewers understand the importance of the peer review process in accordance with the SoW, OMB Guidelines, and ToRs. In addition, the chair will be selected by the contractor and be responsible for facilitating the meeting.

The CIE chair shall serve as an external expert to chair the panel review and have excellent oral and written communication skills. In addition, the chair shall a have working knowledge, recent experience in the application of fisheries stock assessment processes, and results, including population dynamics, integrated statistical age-structured models like Stock Synthesis models and shark biology (reproduction and growth). The chair should also have experience conducting stock assessments for fisheries management.

The reviewers shall also have working knowledge, recent experience in the application of fisheries stock assessment processes, and results, including population dynamics, integrated statistical age-structured models like Stock Synthesis models and shark biology (reproduction and growth). They should also have experience conducting stock assessments for fisheries

management. It is desirable for at least one of the reviewers to be familiar with shark stock assessments.

Tasks for reviewers

1) Review the following background materials and reports prior to the review meeting;

Teo, S. L. H., E. G. Rodriguez, and O. Sosa-Nishizaki. 2016. Status of common thresher sharks, *Alopias vulpinus*, along the west coast of North America. NOAA Technical Memorandum. NOAA-TM-NMFS-SWFSC-557. 196 pp.

Aryafar, H., A. Preti, H. Dewar, and S. Kohin. Reproductive biology parameters for common thresher sharks along the west coast of North America. Document to be developed.

Stock Synthesis model files and other related assessment information published in the interim that is provided by the SWFSC Project Contact.

2) Attend and participate in the panel review meeting. The meeting will consist of presentations by NOAA and other scientists, stock assessment authors and others to facilitate the review, to answer any questions from the reviewers, and to provide any additional information required by the reviewers.

3) After the review meeting, reviewers shall conduct an independent peer review report in accordance with the requirements specified in this SoW, OMB guidelines, and ToRs, in adherence with the required formatting and content guidelines; reviewers are not required to reach a consensus.

4) Each reviewer should assist the Chair of the meeting with contributions to the summary report.

5) Deliver their reports to the Government according to the specified milestones dates.

Specific Tasks for CIE Chair:

The following chronological list of tasks shall be completed in a timely manner as specified in the **Schedule of Milestones and Deliverables.**

1) Conduct necessary pre-review preparations, including the review of background material and reports in advance of the peer review;

2) Participate as the chair during the June 26-28, 2017 panel review meeting at the Southwest Fisheries Science Center in La Jolla, California, and facilitate the panel review maintaining the focus of the peer review in accordance with the ToRs;

3) Produce a Summary Report of the proceedings. The summary report shall not be a consensus report. The independent CIE reviewers should have an opportunity to review

and provide comments or elaboration on any points raised in the summary report that they feel might require further clarification.

Foreign National Security Clearance
When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for reviewers who are non-US citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html. The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance
The place of performance shall be at the contractor's facilities, and at the Southwest Fisheries Science Center in La Jolla, California, USA.

Southwest Fisheries Science Center
Pacific Room
8901 La Jolla Shores Drive
La Jolla, CA 92037
USA

Period of Performance
The period of performance shall be from the time of award through August 18, 2017. The CIE chair and each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

Within two weeks of award	Contractor selects and confirms CIE Chair and reviewers
No later than June 5, 2017	Contractor provides the pre-review documents to the CIE Chair and reviewers
June 26-28, 2017	Panel review meeting
No later than July 7, 2017	The CIE Chair submits a draft Summary Report to the contractor for each of the independent reviewers to review and comment

July 17, 2017	Contractor receives draft independent peer review reports as well as the reviewed draft Summary Report
July 31, 2017	Contractor submits final reports to the Government

Applicable Performance Standards
The acceptance of the contract deliverables shall be based on three performance standards: (1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each TOR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel
All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $10,000.

Restricted or Limited Use of Data
The contractors may be required to sign and adhere to a non-disclosure agreement.

NMFS Project Contact:
Dale Sweetnam
dale.sweetnam@noaa.gov
Deputy Director, Fisheries Resources Division
Southwest Fisheries Science Center
National Marine Fisheries Service
8901 La Jolla Shores Drive
La Jolla, CA 92037
(858) 546-7170

Peer Review Report Requirements

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The report must contain a background section, description of the individual reviewers' roles in the review activities, summary of findings for each TOR in which the weaknesses and strengths are described, and conclusions and recommendations in accordance with the TORs.

   a. Reviewers must describe in their own words the review activities completed during the panel review meeting, including a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each TOR even if these were consistent with those of other panelists, but especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the summary report that they believe might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The report shall represent the peer review of each TOR, and shall not simply repeat the contents of the summary report.

3. The report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of this Statement of Work
   Appendix 3: Panel membership or other pertinent information from the panel review meeting.

Terms of Reference for the Peer Review

Status of common thresher sharks, Alopias vulpinus, along the west coast of North America

1. Evaluate the assessment model configuration, assumptions, and input parameters (e.g., natural mortality, spawner-recruit relationship, reproductive biology) to determine if the data are properly used, input parameters are reasonable, models are appropriately configured, assumptions are reasonably satisfied, and primary sources of uncertainty are accounted for.
2. Evaluate the ability of the model, combined with available data, to assess the current status and productivity of common thresher sharks along the west coast of North America.
3. Evaluate the adequacy of sensitivity analyses to represent the main axes of uncertainty in the assessment.
4. Recommendations for future research priorities and further improvements to the assessment model.
5. Brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations.

Tentative AGENDA
2017 Common Thresher Shark (*Alopias vulpinus*) Stock Assessment Review

Southwest Fisheries Science Center
8901 La Jolla Shores Dr., La Jolla, CA 92037
La Jolla, CA 92037
858-546-7000

This is a public meeting, and time for public comment may be provided at the discretion of the meeting Chair. This is a work session for the primary purpose of reviewing the current Common Thresher stock assessment, under the Center for Independent Experts terms of reference (ToR). The Stock Assessment Review Panel will review the assessment and produce independent reports and in conjunction with the Chair. The Stock Assessment Team (STAT) will provide presentations and all appropriate background information needed for the review.

MONDAY, JUNE 26, 2017 – 10 A.M.

A. Call to Order, Introductions, Approval of Agenda *(10 a.m., 15 minutes)*	Chair, TBD
B. Terms of Reference for Stock Assessment Review Process *(10:15 a.m., 15 minutes)*	Dale Sweetnam
C. Common Thresher Stock Assessment *(10:30 a.m., 1.5 hours)*	Steve Teo, STAT
LUNCH	
D. Common Thresher Stock Assessment (Continued) *(1 p.m., 2 hours)*	Steve Teo, STAT
BREAK	
E. Discussion and Requests *(3:30 p.m., 1 hour)*	Panel
F. ***Public Comment*** ***(4:30 p.m., 0.5 hours)***	

TUESDAY, JUNE 27, 2017 – 8 A.M.

G. Response to Requests *(8:00 a.m., 2 hours)*	Steve Teo, STAT
BREAK	
H. Initial Report Writing and STAT Work Session *(10 a.m., 2 hours)*	Panel
LUNCH	
I. Discussion and Requests	

(1:30 p.m., 1 hour)

J. Public Comment
(2:30 p.m., 0.5 hours)

BREAK

K. Report Writing and STAT Work Session — Panel
(3:30 p.m., 2 hours)

WEDNESDAY, JUNE 28, 2017

L. Response to Requests — Steve Teo, STAT
(8 a.m., 2 hours)

BREAK

M. Discussion and Requests — Panel
(10:30 a.m., 1.5 hours)

LUNCH

N. Response to Requests — Steve Teo, STAT
(1 p.m., 1 hour)

O. Public Comment
(2 p.m., 0.5 hours)

BREAK

P. Discussion – Next Steps and Deadlines
(3 p.m., 1 hours)

Q. Finalize Report Assignments — Chair
(4 p.m., 1 hours)

R. Work Session as Necessary and Meeting Wrap Up — Chair
(5 p.m.)

ADJOURN

4.3 Panel membership or other pertinent information from the Panel review Panel membership or other pertinent information from the Panel review meeting.

Name	Organization	Country
Suzanne Kohin	SWFSC	USA
Henrik Sparholt (Chair)	CIE	Denmark
Joseph Powers	CIE	USA
Rui Coelho	CIE	Portugal
Kevin Hill	SWFSC	USA
P.R. Crone	SWFSC	USA
Heidi Dewar	SWFSC	USA
Hui-Hua Lee	SWFSC	USA
Steven Teo	SWFSC	USA